The Go-Lab Platform, an Inquiry-Learning Space: Investigation into Students' Technology Acceptance, Knowledge Integration, and Learning Outcomes

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Abstract

Utilizing an inquiry-learning space (ILS) via the Go-Lab platform, we investigated students' technology acceptance, knowledge integration [KI] process, and learning outcomes of both the high-achiever KI student and low-achiever KI student. This study aimed to understand how students engage in knowledge integration tasks using an inquiry-learning space to learn Mendelian genetics and realize the relationship between student KI and domain knowledge. We conducted a pre-experimental study with 41 seventh-grade students in Taiwan. The students completed Mendelian genetics KI tasks in ILS, pre/post-testing of domain knowledge tests, and a technology acceptance questionnaire. The analysis of students' interaction in the ILS and domain knowledge tests was conducted through descriptive statistics, *t*-tests, Pearson correlation, and content analysis to indicate the direction and relationship between students' KI processes and learning outcomes. A technology acceptance questionnaire was analyzed through descriptive statistics and Pearson correlation to reveal whether students accepted learning on the Go-Lab platform. The study showed that i) students responded positively to the perceived usefulness of the Go-Lab platform, ii) the high-achiever KI students could gradually construct links from simple to complex and diverse among genetic ideas, and the low-achiever almost built simple links, but iii) the high-achiever and low-achiever KI students had similar learning outcomes. These findings have implications that instruction design of knowledge integration tasks promotes students' Mendelian genetics conceptual understanding and KI progress.

1. Introduction

For many countries, such as the United States, the United Kingdom, and Taiwan, Mendelian genetics is one of the main topics of biology in school science. However, researchers have unanimously found that genetics is conceptually difficult to learn and teach (Ageitos et al., 2019; Cavallo, 1996; Cho et al., 1985; Duncan et al., 2009; Lewis & Wood-Robinson, 2000; Stewart, 1988). Studies showed that some students have difficulty forming conceptual relationships between alleles and cell processes like mitosis and meiosis because students require multi-level thinking and reasoning (Lewis & Wood-Robinson, 2000; Tsui & Treagust, 2003). During the learning process, knowledge integration (KI), adding, evaluating, and problem-solving in terms of scientific ideas, may help students understand deeply(Linn et al., 2006; Liu et al., 2008). Since KI could promote students' understanding of the complex connections among genetic ideas (e.g., trait, allele, gamete, and zygote), KI of Mendelian genetics has rarely been investigated. Therefore, this study aims to provide further insights into students' KI processes of learning Mendelian genetics.

The Go-Lab platform provides virtual labs for simulations, remote labs with equipment accessibility, and data sets so teachers can utilize these resources to design pedagogically structured inquiry learning spaces (ILS) (De Jong et al., 2014). In this way, the Go-Lab offers students an opportunity to enable inquiry-based learning, promoting students' understanding of scientific concepts, problem-solving, and engagement in science. The development of students' capability to engage in scientific inquiry in a scientific context is one of the principal goals of science education (NGSS Lead States, 2013). Similarly, the recent curriculum reforms in Taiwan have encouraged teachers to develop context-based learning so that students can enable their competencies to engage in learning (Ministry of Education, 2014). In short, by providing students with a context-based ILS that comprises authentic problems, students can improve their cognition, skill, and attitude toward science and act like scientists employing scientific inquiry.

Many studies have evaluated that inquiry-based learning can improve learners' scientific literacy and understanding (Fang et al., 2016; Keselman, 2003; Linn et al., 2006; Minner et al., 2010); however, only a few studies have investigated students' engagement in learning Mendelian genetics through online inquiry-based learning, especially on the Go-Lab platform. Accordingly, we aimed to design an ILS, which comprised a context-based scenario, guidance activities, and KI tasks for an investigation into students' conceptual understanding and knowledge integration in the processes of the ILS with the virtual lab; it is essential to understand whether students can accept the technology-supported learning on the Go-Lab platform. In summary, we posed the following research questions:

RQ1. How well do students accept the ILS Go-Lab platform technology for learning?

RQ2. In an ILS, what are the student knowledge integration processes of learning Mendelian genetics

RQ3. What are the learning outcomes of high-achiever [KI] students and low achiever [KI] students, and do they differ?

2. Literature Review

2.1 Inquiry-based Learning and Knowledge Integration

According to the National Research Council (NRC), inquiry refers to "the diverse ways scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry-based learning also refers to activities of students in which they develop knowledge and understanding of scientific ideas and an understanding of how scientists study the natural world." (Council, 1996). Over the past three decades, inquiry-based learning has become an important pedagogy in science education. The newest curriculum guidelines in the United States and Taiwan promote this approach to assist students in understanding and constructing scientific conceptions (Council, 1996; Ministry of Education, 2014; NGSS Lead States, 2013).

Pedaste et al. (2015) analyzed 32 articles describing the inquiry phase and summarized the five general inquiry phases: orientation, conceptualization, investigation, conclusion, and discussion, as shown in Figure 1. By offering learning tasks and scientific problems, the orientation phase focuses on stimulating interest and curiosity, and it follows up the conceptualization phase that claims concepts of the investigable problems. The investigation phase is where students turn curiosity into action to solve and respond to the research questions or hypotheses. As students have finished experiments and collected data, they should draw an evidence-based conclusion responding to their original research questions or hypotheses in the conclusion phase. Last but not least, the discussion phase occurs when students reflect and communicate on the whole process at the end of a single phase in the cycle.

Previous studies have already pointed out that inquiry-based learning can promote students' exploring, reasoning, modeling competencies, and academic achievement (Campbell et al., 2015; Chinn & Malhotra, 2002; Sullivan et al., 2017; Ulus & Oner, 2020; White & Frederiksen, 1998; Zimmerman, 2007). The process of scientific inquiry is central to reasoning involving hypothesis, experimental design, evidence evaluation, and drawing inferences (Zimmerman, 2007). Authentic tasks, classified into hands-on inquiry, computer-simulated experimentation, database tasks, evidence evaluation tasks, and verbal designs of research, play an important role in fostering the development of epistemologically scientific reasoning. In particular, the advantage of simulation tasks is that they allow students to test with complex underlying models that they could not do in reality because of lack of time and equipment (Chinn & Malhotra, 2002).

Knowledge integration (KI) is an approach to assessing complex science reasoning; moreover, in recent years, research has applied the KI framework to measure science inquiry processes, such as the ability to link ideas, distinguish among ideas, and generate arguments (Fang et al., 2016; Linn, 1995; Linn et al., 2006; Liu et al., 2008; Ulus & Oner, 2020). Clark and Linn (2003) mentioned that learners could expand, revise, restructure, and reconnect their ideas through effective teaching. Students' knowledge integration is dynamic during inquiry-based learning; hence, we design the ILS with knowledge integration tasks to monitor students' genetic learning.

2.2 The Go-Lab platform with Virtual Labs

Go-Lab is an online learning platform where students can engage in inquiry-based learning in a structured and supportive way (Hovardas et al., 2018). By providing a federation of virtual and remote laboratories and data sets, referred to as "online labs," the Go-Lab platform offers teachers opportunities to embed these online labs in pedagogically structured and inquiry learning spaces (ILSs) (De Jong et al., 2014). ILSs are online and digital environments where students interact with the learning material, including virtual labs and other multimedia resources, such as text and images (de Jong et al., 2021). In short, ILSs can provide students with a context-based environment and instructional guidance for learning.

With advanced technology, inquiry-based learning can use digital instruments, such as interactive visualizations and virtual laboratories, to assist students in solving problems and understanding complex scientific ideas (De Jong et al., 2013; Linn et al., 2006). Virtual investigations can equal or exceed the influence of physical investigations on conceptual understanding; many studies show no significant differences in conceptual understanding or inquiry competency between physical and virtual experiments (Brinson, 2015; De Jong et al., 2013; Heradio et al., 2016). Many online learning ecosystems, such as Go-Lab, WISE, and PhET, offer students virtual laboratories, which simplify learning by highlighting salient variables, removing confusing details, and modifying time scales to explore and investigate the scientific phenomenon easier (De Jong et al., 1998; Gnesdilow & Puntambekar, 2021; Potkonjak et al., 2016).

The virtual lab is an effective way to elicit students' understanding of the nature of science (NOS) (De Jong et al., 2013). Knowing something about how scientific knowledge is generated and the limits of scientific knowledge is an essential aim of scientific literacy (American Association for the Advancement of Science, 1993; Ministry of Education, 2018; NGSS Lead States, 2013). Regarding the approaches for learning and teaching the NOS, the implicit approach attempts utilized engagement in inquiry-based learning activities to improve understanding of NOS; on the other hand, the direct approach to learning NOS attempts to utilize certain scientific content, such as history and philosophy of science (Abd-El-Khalick & Lederman, 2000; Schwartz et al., 2004). Develaki (2019) demonstrated an example of supporting NOS understanding by simulation experiments. In summary, we can use the Go-Lab platform to build an ILS embedded with virtual labs for improving students' understanding of scientific concepts and the nature of science.

2.3 Learning of Mendelian Genetics

Mendelian genetics is an essential concept of heredity in the United States and Taiwan school science. When teaching about heredity, the history and work of Mendel are incorporated (Ministry of Education, 2018; NGSS Lead States, 2013). Taking the Next Generation Science Standards (NGSS), for example, inheritance of traits is one of the disciplinary core ideas. NGSS suggested that Gregor Mendel and the laws he formed can be included when teaching about heredity. Concepts of Mendelian genetics contain dominance, segregation, and independent assortment that relate to the microscopic entities, such as gametes and alleles. Similarly, genetics is one of the learning contents in Taiwanese curriculum guidelines. Regarding Mendelian genetics, seventh-grade students in Taiwan must learn monohybrid crosses, and tenth-grade students are expected to learn dihybrid crosses.

However, due to the abstract and complex links among genetic ideas, students are likely to encounter difficulties when they are asked to describe how the following concepts are related: allele, trait, gamete, and zygote (Allen, 1987; Cho et al., 1985; Stewart, 1988; Stewart, 1982; Tsui & Treagust, 2007). Several studies have attempted to find alternative concepts in genetics and the reasons for the difficulties in learning genetics. One alternative concept is that students do not relate heterozygous and homozygous alleles to the law of dominance. Similarly, students may misunderstand the linked dominant or recessive alleles for two traits (Cho et al., 1985; Stewart, 1983). The other alternative concept concerns dihybrid crosses in which students fail to construct allelic keys and determine the genetic composition of the parental gametes (Browning & Lehman, 1988; Cho et al., 1985; Stewart, 1982).

Mendelian genetics has been widely investigated in genetics problem-solving studies (Browning & Lehman, 1988; Corbett et al., 2010; Slack & Stewart, 1990; Tsui & Treagust, 2003) because students can understand genetics at a deeper level by using existing conceptual knowledge to solve problems or discover the new relationship among concepts (Stewart, 1988; Tsui & Treagust, 2010). Due to genetics experiments would be very difficult to do in the classroom, several studies have focused on computerized learning environments to support the development of students' understanding, problem-solving, and reasoning of genetics (Buckley et al., 2004; Tsui & Treagust, 2003; Tsui & Treagust, 2010; Tsui & Treagust, 2007). In such learning environments, students could manipulate the links of variables that helped students develop connections among genetic entities; therefore, learning genetics through simulations supported conceptual understanding (Hickey et al., 1999; Tsui & Treagust, 2003; Tsui & Treagust, 2007). Although previous findings suggest that genetics problem-solving learning activities support students' learning outcomes, there was a noticeable absence of research projects that offer students both evidence evaluation and simulation experiment tasks as scaffolding for learning Mendelian genetics. Thus, this study applies a scaffolding for learning through ILS to help students understand Mendelian genetics' complex and abstract ideas.

2.4 Technology Acceptance Model

Technology Acceptance Model (TAM) was first proposed by Davis (1989) as a diagnostic tool for evaluating and predicting whether digital device users accept a new information technology system. Numerous studies have used TAM for 20 past years (Ali et al., 2016; Cairns et al., 2021; Dasgupta et al., 2002; Gnidovec et al., 2020; Teo, 2009; Zhai & Shi, 2020); thus, TAM has become well-established as a robust and powerful model for investigating user acceptance. TAM consists of five variables that are described as follows (Davis, 1989; Davis et al., 1989; Venkatesh & Davis, 1996, 2000): (1) External Variables：Any factors that indirectly affect behavior, such as system design characteristics, user's cognitive style, task characteristics, political factors, etc. (2) Perceived Usefulness：An individual believes that whether a particular system can be used to improve work performance. (3) Perceived Ease of Use：An individuals consider whether they can easily use a particular system with little or no effort. (4) Behavioral Intention：Whether an individual is willing to use a particular system. (5) Actual System Use：Whether an individual uses a particular system. According to TAM, an individual's behavioral intention to use a system is determined by perceived usefulness and ease of use, and perceived usefulness is also affected by perceived ease of use (Venkatesh & Davis, 2000). In summary, for investigating students' acceptance of learning in the ILS, we adopted TAM as the framework to design the Go-Lab platform acceptance questionnaire.

3. Materials And Methods

3.1 Mendelian Genetics Concepts and Experiments

The main concepts of Mendelian genetics in school science are Mendel's laws of inheritance, including the law of dominance, segregation, and independent assortment. This study used virtual rabbits inside the virtual lab as the model organism with two obvious traits: ear shape and fur color. Hence, students would study Mendelian genetics through an inquiry-based approach. Based on the law of dominance and segregation, students could explain the 3:1 inheritance pattern and distinguish between the dominant trait and recessive trait of those characters through monohybrid crosses, respectively, by designing and conducting an experiment in the virtual lab to collect breeding data. The law of independent assortment involved two pairs of alleles, and its complexity usually led to students' alternative concepts. Accordingly, we adopted one of the common alternative concepts (Stewart, 1982) that the two different pairs of alleles for two characters assort into gametes dependently or independently to construct the two hypotheses for predicting the pattern of two-trait inheritance law (Figure 2). By providing a dihybrid crosses diagram, students could illustrate how different the alleles assort into gametes. After simulating the crosses of rabbits, they inferred the correct hypothesis of assortment in an evidence-based way. Students would be expected to construct a link or links among genetic ideas to demonstrate the dihybrid cross model (e.g., trait, allele, gamete, zygote). However, Mendel's inheritance laws applied only to genes located on different chromosomes or very far apart genes on the same chromosome because Mendel did not detect linkage and genetic recombination. Thus, the limitations of Mendelian genetics played an important role in helping students understand the limitations of the scientific model.

3.2 Structured and Context-based ILS

Researchers used apps and virtual labs to design the ILS (Figure 3) on the Go-Lab, set in the context-based scenario and based on the inquiry-learning framework (Pedaste et al., 2015); therefore, the first author and the second author established a scenario in which students had to help their seniors complete the unfinished research on rabbits' genetics in the ILS. Scientific clues, uncompleted manuscripts, and the virtual lab offered students direction to learn Mendelian genetics through an inquiry-based approach. The design of KI tasks in the ILS is from simple to complex and from monohybrid crosses to dihybrid crosses to the limitation of Mendelian genetics.

The ILS consisted of two sections that included learning activities and KI tasks, including evidence evaluation tasks and simulation experiment tasks, which followed the suggestion of Chinn & Malhotra (2002). Learning activities offered guided descriptions and a virtual lab where students could follow these materials to conduct the rabbits' genetics research structurally; thus, after the learning activity, students could solve the evidence evaluation problems, analyze the collected data from the virtual lab and argue the view of scientific model' limitation in response to the KI task. A full description of the ILS can be found in Appendix 2. Descriptions of the KI tasks in the ILS are provided in Table 1.

Table 1. The KI tasks for learning Mendelian genetics in the ILS

Task no	Main concept	The objective of the KI task
1	Dominance	A simulation experiment task. Using the prior knowledge and simulation data to solve which trait is dominant or recessive.
2	Dihybrid crosses	An evidence evaluation task. Demonstrating two inheritance patterns of dihybrid crosses with the reports.
3	Independent assortment	A simulation experiment task. Using the prior knowledge and simulation data to test which hypothesis is correct.
4	Dihybrid crosses	A reflecting task. Demonstrating the inheritance patterns of dihybrid crosses again.
5	Mendelian Genetics	A reflecting task. Considering the limitation of the scientific model.

As shown in Figure 4, the first section, in which the main concept was monohybrid crosses, provided two learning activities and one KI task. The second section, whose main concept was dihybrid crosses, provided two activities and four KI tasks. The activities demonstrated the senior unfinished research to stimulate students' interest and curiosity in the first section. KI task 1 was a simulation experiment task in which students would design an experiment and simulate breeding experiments through the virtual lab to help them distinguish between the dominant and recessive traits of rabbits, such as the fur color and ears shape. In addition, by providing a fundamental task, students could become familiar with using the Go-Lab platform for learning.

In the second section, the unfinished report of the two hypotheses, dihybrid crossed between a black fur and straight ears rabbit and a white fur and folded ears rabbit, was shown in activity 3. KI task 2 was an evidence evaluation task in which students could try to comprehend the report and demonstrate the model of alleles' assortment. After that, students simulate hybridization experiments in the virtual laboratory to test which hypothesis fits in KI task 3. In the final phase, students were expected to reflect on their former responses to dihybrid crosses and demonstrate the model again; they would also think nature of the science problem and whether this inheritance model could fit every organism.

3.3 Go-Lab Platform Acceptance Questionnaire

This questionnaire was designed to investigate students' technology acceptance of the ILS anonymously on the Go-Lab platform after experiencing it. Based on TAM (Davis, 1989; Davis et al., 1989; Venkatesh & Davis, 1996, 2000), all the items were applied to a Likert five-point scale (5 = strongly agree to 1 = strongly disagree). The questionnaire is composed of three variables as follows: perceived usefulness (PU), perceived ease of use (PEU), and behavior intention (BI). There are five items in PU, six items in PEU, and three items in BI (Appendix 3). The Cronbach's alpha was utilized to test the questionnaire's internal consistency of three variables. The Cronbach's coefficient ranged from .902 to .929, suggesting a strong internal consistency.

3.4 Mendelian Genetics Learning Outcome - Domain Knowledge Test

Due to the short time interval between the pre-test and the post-test, we selected two different sets of twenty multiple-choice questions from the west bank of the entrance examinations and midterm tests in Taiwan to build the pre-test and post-test to minimize the test effects. These tests' difficulty and problem types were similar, and the central concepts were the same. The pre-tests aimed to measure students' prior knowledge of Mendelian genetics, such as dominance, segregation, and independent assortment, whereas the post-test would measure students' learning outcomes. The questions were categorized into the basic and advanced parts of each test. The basic part contained thirteen items, and the main concepts of this part were dominance and segregation, which related to monohybrid crosses; on the other hand, the advanced one contained seven items, and the main concept of this was an independent assortment, a central law of dihybrid crosses. The items of the domain knowledge test were scored dichotomously, with 1 or 0 given for correct or incorrect answers, and the higher scores showed a better understanding of Mendelian genetics. Cronbach's alpha for the pre-test and the post-test were .820 and .724, respectively; thus, each test had good internal consistency.

3.5 Knowledge Integration Rubrics

We used a knowledge integration framework to assess and score responses (Liu et al., 2008), including tasks 1 to 5. Knowledge integration framework, including link ideas, distinguishes among ideas and generates arguments based on normative ideas, refers to the five levels progressively distinguished. A score of five was given for the complex link response, including two or more scientifically valid links between normative and relevant ideas. A score of four was the full link response in students who made at least one full link between two relevant and normative concepts. A score of three was the partial link response that was not elaborated enough to demonstrate how two concepts are connected. A score of two was the no-link that students used non-normative ideas and non-normative links, whereas scores of one and zero were given for off-task and no response. Researchers applied the rubrics to assess students' open-ended responses to the KI tasks (). The scores of KI rubrics ranged from 0 to 5 and indicated increasing sophistication of knowledge integration. The 39% responses in the ILS were scored by the first authors and one experienced teacher individually by using the rubrics. We examined the inter-rater reliability for each response and achieved an excellent agreement (Cohen's Kappa = .605 to .796); then, the first author scored the remaining data.

3.6 Procedure and Participants

As shown in Figure 5, single-group pre-experimental research with a pre-test and post-test scheme was adopted to evaluate students' use of the ILS on the Go-Lab platform. Students were required to complete the ILS individually in 2 hours to experience the genetics class on the Go-Lab platform. Datalog files for subsequent analysis captured students' interaction in the ILS. As students finished the ILS, the first authors and one experienced teacher evaluated and scored students' responses by the KI rubrics. The domain knowledge test pre-test and the post-test were administered 30 minutes before and after students completed the learning tasks in the ILS. After the post-test, students continued to finish the Go-Lab platform acceptance questionnaire.

The ILS was open to the mathematically and scientifically gifted students in a junior high school in northern Taiwan, though dihybrid crosses were taught in tenth grade. One reason was to avoid students who have already learned the concepts; the other reason was such gifted students that tend to learn the advanced concepts in math and science. The total number of participants in this study was 41 seventh-grade students. Before this study, these seventh graders had already learned reproduction, cell division, and monohybrid crosses of Mendelian genetics; they had not used the Go-Lab platform.

3.7 Data collection and analysis

According to the research questions, the data collection for our analyses were as follows: (a) applying the KI rubrics to assess students' responses in the ILS, (b) a content analysis was employed to evaluate students' KI responses, especially task 2 and task 4, in terms of genetics concepts, (c) students' pre-test and post-test of a domain knowledge test and (d) students' Go-Lab platform acceptance questionnaire.

We used IBM SPSS Statistics 23.0 software to conduct quantitative analysis. We conducted a paired sample *t*-test and independent *t*-test to detect the significant difference among students' knowledge integration performance in each task and learning outcomes; furthermore, data was also calculated effect size because of the small sample size in this study. A Pearson product-moment correlation method examined any relationships among students' scores on the domain knowledge tests and the tasks and any relationship among PU, PEU, and BIs.

4. Results

4.1 Technology Acceptance of the Go-Lab platform

Students showed a greatest level of agreement with perceived usefulness ($M = 4.053$, $SD = .643$) and then subjectively showed a moderate level of agreement with perceived ease of use ($M = 3.723$, $SD = .933$) and behavioral intention ($M = 3.862$, $SD = .922$). presents the means and standard deviations for technology acceptance. Students strongly agree with the statement, "I generally find it useful to use ILS in science learning" (PU5). "Using ILS will improve my learning efficiency" (PU3), and "ILS provides abundant learning resources and supplementary materials, which can improve my learning outcome" (PU4). On the contrary, they most disagree with the following items: operating the gadgets in ILS is easy for me (PEU2), and interaction with ILS does not require much mental effort (PEU3). These findings suggested that students agreed that the ILS on the Go-Lab platform improved learning efficiency effectively but showed moderate favor for PEU and BI. In addition, we found statistically significant correlations among PU, PEU, and BI. First, both PU and PEU did correlate positively with BI, $r = .743$, $p < .001$ and $r = .810$, $p < .001$, respectively. Besides, there were a significant correlation between PU and PEU, $r = .752$, $p < .001$.

Table 2. technology acceptance of the Go-Lab platform by students (N=41)

Variable	Item	M	SD
Perceived usefulness (PU)	PU1	3.951	0.740
	PU2	4.024	0.790
	PU3	4.098	0.664
	PU4	4.049	0.773
	PU5	4.146	0.691
Perceived ease of use (PEU)	PEU1	3.854	0.989
	PEU2	3.366	1.220
	PEU3	3.537	1.142
	PEU4	3.829	0.998
	PEU5	3.780	1.129
	PEU6	3.976	0.851
Behavioral intention (BI)	BI1	3.927	0.985
	BI2	3.780	1.061
	BI3	3.878	0.927

4.2 Knowledge Integration Process in the ILS

This study investigated students' KI in the processes of the ILS that offer a structured and context-based environment for learning Mendelian genetics. We divided students into high and low groups regarding their all scores on the KI tasks. The median of all scores was 17; thus, students whose scores were equal or higher than 17 were categorized as the high-achiever knowledge integration group (high KI group) (N=21), and those whose scores were lower than 17 were categorized as the low-achiever knowledge integration group (low KI group) (N=20). Descriptive statistics concerning students' KI performance in each task are summarized in Table 3 (mean and standard deviation) and Figure 6 (percentage of KI level).

Table 3. Mean and standard deviation of students' KI tasks.

	All (N=41)		High (N=21)		Low (N=20)	
Task no (description)	Mean	SD	Mean	SD	Mean	SD
1 (dominance)	3.415	0.948	3.762	0.436	3.050	1.191
2 (two hypotheses)	2.488	1.165	3.095	0.768	1.850	1.182
3 (testing hypotheses)	2.927	1.058	3.381	0.498	2.450	1.276
4 (reflecting)	3.341	1.697	4.429	0.746	2.200	1.673
5 (limitation)	2.854	1.352	3.619	0.740	2.050	1.395
Average	3.005	0.890	3.657	0.201	2.320	0.814

In comparing simulation experiment tasks, we have carried out paired samples *t*-tests of monohybrid crosses experiment (task 1) and dihybrid crosses experiment (task 3) in Table 4. There was a significant difference in scores of all students for responses in monohybrid crosses (M = 3.415, SD = 0.948) and dihybrid crosses (M = 2.927, SD = 1.058), $t\ (40) = 2.545$, $p < .05$ with a medium effect size (Cohen's d = .486). There was a significant difference in scores of the high KI group in monohybrid crosses (M = 3.762, SD = 0.436) and dihybrid crosses (M = 3.381, SD = 0.498), $t\ (20) = 2.961$, $p < .01$ with a large effect size (Cohen's d = .814). In contrast, the result showed no difference in the low KI group scores, $t\ (19) = 1.610$, $p = 0.124$. These results indicated that students' KI between the simulation experiment data and the scientific concept, particularly the high KI group, depended on their conceptual proficiency.

Table 4. Results for students' KI level of monohybrid and dihybrid crosses

All (N=41)			High KI group (N=21)			Low KI group(N=20)		
t	*p*	d	*t*	*p*	d	*t*	*p*	d
2.545	.015	.486	2.961	.008	.814	1.610	.124	.486

In Table 4, according to students' knowledge integration of the dihybrid crosses model, when students performed the evidence evaluation task (task 2), the link between alleles and gametes was the most among the links in the high KI and low KI group, and two responses of the high KI group were the link between traits and alleles; besides. There were five students of the high KI group and seventeen students of the low KI group who did not link (level 2), were off-task (level 1), or had no answer (level 0).

#T2B70303: *The pattern of hypothesis 2 is that alleles would be assorted randomly to gametes.* (AG)

#T2B72536: *Hypothesis 2 shows four combinations of traits, including black fur and straight ear, black fur and folded ear, white fur and straight year, and white fur and folded year. These traits result from an independent and random assortment of alleles.* (TA)

Since students had conducted a simulation experiment, the high KI group showed the diverse and complex links among genetic ideas in the reflection task (task 4), but the low KI group showed only simple or single links. All students of the high KI group could make at least one link, eight students connected two links, and four students even showed over two links. Over half of the low KI group students could link, and one student made two links. The results revealed that the high KI group was likely to construct the complex dihybrid crosses model with several links among traits, alleles, gametes, and zygotes.

#T4A70711: *(1) The two traits inherit independently and do not affect each other. (2) When the offspring want to obtain alleles, they are composed of the alleles randomly separated from the parents. (3) As the traits are expressed, they are decided by the dominant alleles. For example, AaBb will express the traits of A and B, respectively.* (AG/TA/GZ)

Table 5. Knowledge integration of the dihybrid crosses model in task 2 and task 4

Task no	Group	Link(s) among genetic ideas	Number of responses
2	High KI group	AG	13
		TA	3
	Low KI group	AG	3
4	High KI group	AG	6
		TA	3
		AG/TA	4
		AG/GZ	4
		AG/TA/GZ	4
	Low KI group	AG	11
		AG/TA	1

Note: AG is the link between alleles and gametes, TA is between traits and alleles, and GZ is between gametes and zygotes.

In comparing the KI level of the dihybrid crosses model, we have carried out paired samples *t*-tests to examine those tasks (task 2 and task 4) before and after the simulation experiment in Table 6. There was a significant difference in scores of all students for KI before the simulation experiment ($M = 2.488$, $SD = 1.165$) and after the simulation experiment ($M = 3.341$, $SD = 1.697$), $t(40) = -3.545$, $p < .01$ with a medium effect size (Cohen's $d = .587$). There was a significant difference in scores of the high KI group for KI before the simulation experiment ($M = 3.095$, $SD = 0.768$) and after the simulation experiment ($M = 4.429$, $SD = 0.746$), $t(20) = -5.502$, $p < .001$ with a large effect size (Cohen's $d = 1.760$). In contrast, the result showed no difference in the low KI group scores, t (19) = -.877, p = 0.242. The results indicated that as students, particularly the high KI group, finished both the evidence evaluation task and the simulation task of dihybrid crosses, they would perform significantly high knowledge integration levels.

Table 6. Results of students' KI in demonstrating the model of dihybrid crosses (task 2 and task 4)

All (N=41)			High KI group (N=21)			Low KI group(N=20)		
t	*p*	d	*t*	*p*	d	*t*	*p*	d
-3.545	0.001	0.587	-5.502	.000	1.760	-.877	.392	.242

Table 7 presents a 5 x 5 matrix of Pearson product-moment correlation coefficients on the students' KI tasks scores. Our analysis showed significant correlations among task 2, 3, 4, and 5 scores. Moreover, the task 1 score correlated significantly with task 4. The results reveal that students' KI in task 2 was associated with the performance on the subsequent tasks.

Table 7. Summary of correlations among the students' KI tasks scores

Task no	1	2	3	4	5
1 (dominance)	1				
2 (two hypotheses)	0.016	1			
3 (testing hypotheses)	0.255	0.537**	1		
4 (reflecting)	0.345*	0.470**	0.446**	1	
5 (limitation)	0.049	0.618**	0.447**	0.425**	1

Note: **. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.3 Students' Prior Knowledge and Learning Outcome

The improvement of domain knowledge in different KI achiever groups is compared in this section. As regards students' prior knowledge, the result (see Appendix 5) shows both the high achiever and the low KI group performed well (M = 11.640 to 12.000) in the basic part but moderately in the advanced part. An independent *t*-test was conducted to examine the difference of the pre-test between the high achiever and the low KI group. The tests of the basic part (t (39) = 1.358, p = .182, d = .424), advance part (t (39) = 1.352, p = .184, d = .421) and total part (t (39) = 1.641, p = .109, d = .511) were not statistically significant (see Appendix 6). As regards students' learning outcome, an independent *t*-test, likewise, was conducted to examine the difference of the learning outcome between the high achiever and the low KI group. The tests of the basic part (t (39) = .512, p = .612, d = .159), advance part (t (39) = -.146, p = .885, d = .045) and total part ((t (39) = .216, p = .830, d = .067) were not statistically significant.

A paired sample *t*-test was conducted to evaluate the high KI group's and the low KI group's improvement of domain knowledge. In Table 8, the results of the basic part showed no significant improvement of both the high KI group (t (20) = .439, p = .666 , d = .100) and the low KI group (t (19) = -.165, p = .871 , d = .042); the results of the advanced part showed significant improvement of both the high KI group (t (20) = -2.256, p < .05, d = .580) and the low KI group (t (19) = -3.777, p < 0.01 , d = .879).

These results suggested that (a) participants' prior knowledge and learning outcomes were not different between the high KI group and the low KI group, (b) the participants were proficient in monohybrid crosses, so it could not find significant improvement, and (c) the ILS could support both the high and the low KI group to learn the concepts of Mendelian genetics from monohybrid crosses to dihybrid crosses.

Table 8. Paired samples *t*-test for students' domain knowledge tests

Part	All (N=41)			High KI group (N=21)			Low KI group (N=20)		
	t	*p*	d	*t*	*p*	d	*t*	*p*	d
BP	.133	.895	.022	.439	.666	.100	-.165	.871	.042
AP	-4.269	.000	.738	-2.256	.035	.580	-3.777	.001	.879
Total	-3.215	.003	.470	-1.826	.083	.346	-2.692	.014	.575

Note: BP was the basic part of the domain knowledge test, composed of monohybrid crosses concepts; AP was the advanced part, composed of dihybrid crosses concepts.

5. Discussion

5.1 Positive acceptance of the Go-Lab platform

The Go-Lab platform acceptance questionnaire results demonstrated that students strongly agreed with the perceived usefulness of the Go-Lab platform but moderately agreed with both perceived use of ease and behavior intention. The possible reason for the greatest level of perceived usefulness may lie in the advanced learning outcome because there was a significant improvement in conceptual understanding of Mendelian genetics. This finding echoes previous studies that perceived usefulness positively correlates with learning performance through technology-based learning (Alqahtani & Mohammad, 2015; Zhai & Shi, 2020). Students took a lot of mental effort to interact with the ILS concerning the perceived use of ease. According to the descriptive statistics of PEU, one partial explanation may account for the difficulty of operating gadgets on the Go-Lab platform.

Behavior intention correlated positively and significantly with perceived usefulness and ease of use. Our findings are compatible with the empirical studies mentioned in the literature review. There was also a significant correlation between perceived usefulness and ease of use. The findings were consistent with Venkatesh and Davis's proposed TAM (2000).

The present findings contribute to the encouragement of using the Go-Lab platform for designing inquiry-based learning lessons online. Our study suggests that students accept a structured and context-based ILS to understand scientific concepts. However, a related issue concerns the inconvenience of using the ILS. As perceived usefulness and ease of use are primary drivers for the increased intention of users and acceptance of the technology (Davis et al., 1989), the Go-Lab platform was developed to provide an easily accessible user interface, gadgets, and environment. Despite the Go-Lab platform's advantages, it does have some notable limitations. First, the design of an ILS may result in different acceptance levels among users. Next, the participants were selected in the capital city of Taiwan, so all of them were familiar with using digital devices. Particularly the fact is that the main language of the Go-Lab platform is English; nevertheless, it could be prompt some technical problems using the Chinese version of this platform. Despite these limitations, this study provides new insight into learning science.

5.2 Knowledge Integration Process from Monohybrid to Dihybrid Crosses

The students' responses to the KI tasks revealed that students who have already learned monohybrid crosses could build a scientific model of dihybrid crosses by providing KI tasks. The following summarizes some reasons for students' performance in the ILS. First, the sequence of the KI tasks, which provided a fundamental and straightforward task, may help students interact with the platform; they could get familiar with such a technology-supported environment. In task 1, students had to conduct a simulation experiment in the virtual lab for making predictions and interpreting outcomes of the dominant and recessive traits. They experienced the operation of the Go-Lab platform (e.g., the user interface and the virtual lab). Based on the students' performance on task 1, they had a high-quality KI response ($M = 3.415$, $SD = 0.948$) that generally expressed potential connections between trait and dominance. Therefore, this finding ensures that students can do the subsequent KI tasks without a technical problem.

The comparison between the simulation tasks (task 1 and task 3) showed that students performed better on the monohybrid crosses task than on the dihybrid crosses, possibly due to students' excellent prior knowledge of monohybrid crosses ($M = 11.829$, $SD = .834$). This finding contradicts the empirical research that problem-solving achievement related to prior knowledge (Glasson, 1989; Yenilmez et al., 2006). Before the simulation dihybrid crosses experiment, the ILS provided an evidence evaluation task to make students interpret the two possible patterns of dihybrid crosses hypotheses (e.g., allele assortment, segregation, gamete, offspring, parent, trait). Approximately 46% of the participants could reason a partial-link model and a full-link model. This finding aligns with previous studies that evidence evaluation tasks could foster students' development of scientific conceptual understanding (Chinn & Malhotra, 2002; Linn, 2000; Ulus & Oner, 2020). After that, students experimented in the virtual lab to collect data for testing hypotheses. Then they would make meaning of the collected data and conclude the correct pattern of dihybrid crosses. In the evidence evaluation task, most students whose KI level reached above partial link demonstrated the link between allele and gamete. The ILS helped students of the low KI group build the link among genetic ideas. It was noted that the high KI group could make the more complex and diverse links in the reflection task.

Furthermore, we used paired samples *t*-test to examine the difference in students' KI results before and after simulating dihybrid crosses and found a significant advance in the KI level. One explanation for this is that simulation experiments assist students in understanding complex ideas (De Jong et al., 2013; Linn et al., 2006); furthermore, this finding is in complete agreement with Develaki's (2019) claims that the use of simulations can support students' reasoning and evaluation abilities. Accordingly, they could revise and find more connections among genetics ideas and construct a more complex model in terms of KI. Davis (2000) and Leijen et al. (2012) research implied that reflection provides scaffolding to support students to think about the ideas again and reach specific levels of quality. We speculated that the reflecting task in the ILS encouraged students to engage in the KI process, such as restructuring the links among ideas. These findings reveal that the evidence evaluation and simulation tasks enhanced students' conceptual understanding of dihybrid crosses.

Regarding the last reflection task, students were expected to acquire an awareness of NOS through the inquiry process. Pearson product-moment correlation among KI tasks' scores indicates that students' knowledge integration of NOS was associated with addressing dihybrid crosses. However, approximately 76% of the high achievers could explain the limitation of Mendelian genetics with a full link, but approximately 65% of the low achievers made no response, were off-task, or had a no-link answer. Several empirical studies (Bell & Linn, 2000; Develaki, 2019; Smith & Gericke, 2013) attempted to engage students in implicit and explicit NOS learning activities for enhancing their NOS concepts; nevertheless, we need to exercise caution in its interpretation due to not measuring students' initial NOS understanding. These findings suggest that students whose KI reached a high level may deeply understand the limitation of applying Mendelian genetics.

5.3 Relationship between KI and learning outcomes

When we make students engage in a learning program, they would be expected to acquire conceptual understanding. This study indicated that the high KI group and low KI group significantly improved their conceptual understanding of dihybrid crosses; thus, the ILS with KI tasks helps students learn from simple to complex genetics concepts. However, they had no significant learning outcome after performing the ILS. Possibly the KI improvement facilitated better and more equal learning outcomes for students, thus reducing the difference in learning outcomes between KI performance and final achievement. This finding could provide some empirical evidence to claim that the multi-level KI among students would not result in increased differentiation of students' learning outcomes and is in line with a prior study (Johnson & Lawson, 1998) in which researchers found that the reasoning improvement reduced the correlation between reasoning ability and biology achievement in college students.

6. Conclusion And Limitations

The present study designed an ILS on the Go-Lab platform to help learners engage in inquiry-based learning and knowledge integration of genetics. We demonstrated students' KI processes of learning Mendelian genetics and addressed domain knowledge with different KI levels. The study also focused on the technology acceptance of the participants because they were expected to learn Mendelian genetics on the Go-Lab platform. This study identified that the Go-Lab ILS introduced KI tasks, which contained simulation experiments, evidence evaluation, and reflection tasks could effectively promote students' learning outcomes. Findings showed that students viewed the Go-Lab ILS as a useful approach to improving Mendelian genetics' conceptual understanding. Results, by comparison, showed there were different knowledge integration processes between high-achievers and low-achievers. The high KI group could gradually construct links from simple to complex and diverse among genetic ideas and understand the limitation of the dihybrid cross model, but the low KI group tended to build only simple links. Interestingly, the low KI group achieved similar results to the high KI group via structured and context-based ILS on learning outcomes. The research findings provide insight for an opportunity to learn genetics concepts using the Go-Lab platform among various KI levels students.

There are also some limitations derived from the single-group pre-experimental design because of the lack of a control or comparison group. Hence, the participants were divided into the different KI achievement levels that provided an insight into students' KI processes and learning outcomes. Besides, Schmid et al. (2009) have conducted a meta-analysis of 231 studies for exploring the achievement effects of computer-based technology and found that true, quasi-, and pre-experimental designs showed no significant difference. Also, the learning content refers to the senior high school curriculum. In order to avoid the history effect, we did not choose senior high school students but the mathematically and scientifically gifted seven-graders. Although the sample in the study was small, the recommendations could serve as some general pattern for instructors and curriculum designers. Last, despite all limitations of our research, it is hoped to serve as a basis for further research in inquiry-based learning on the Go-Lab platform for knowledge integration of different disciplines.

Declarations

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Competing interests The authors declare no competing interests

Ethics approval This study followed the ethical standards of a social science study.

Consent Statement Informed consent was obtained from all individual participants included in this study. All of the participants voluntarily participated in the study.

Code Availability SPSS basic package.

Data Availability All data and materials are available from the authors.

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Figures

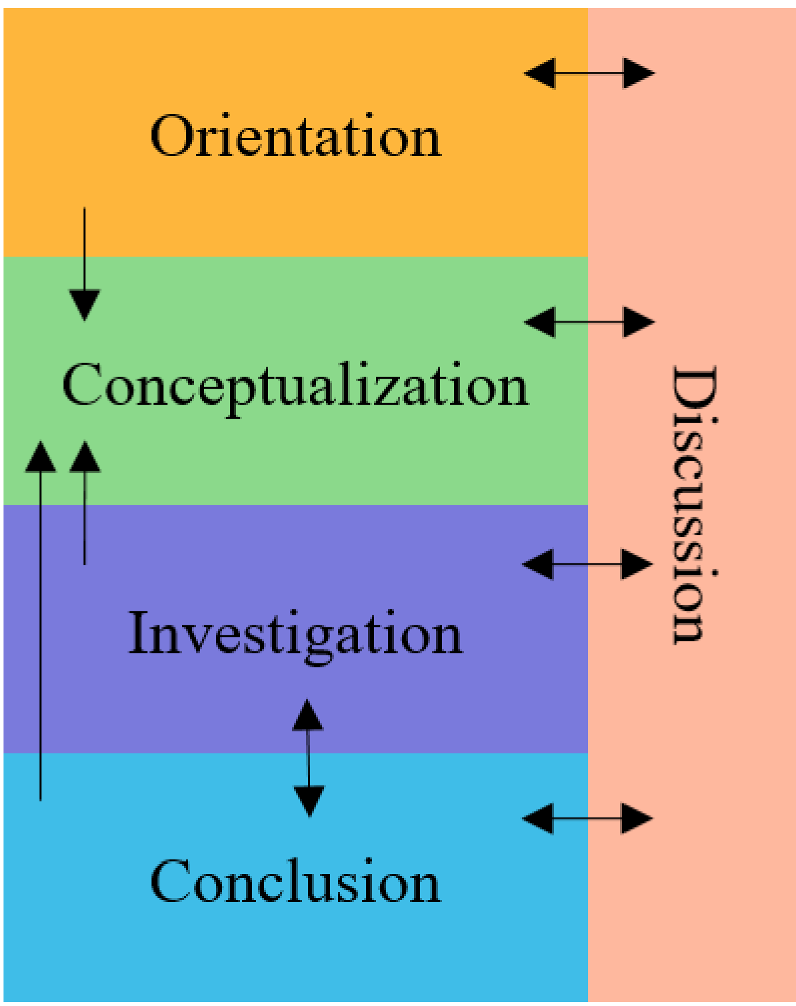

Figure 1

Inquiry phase

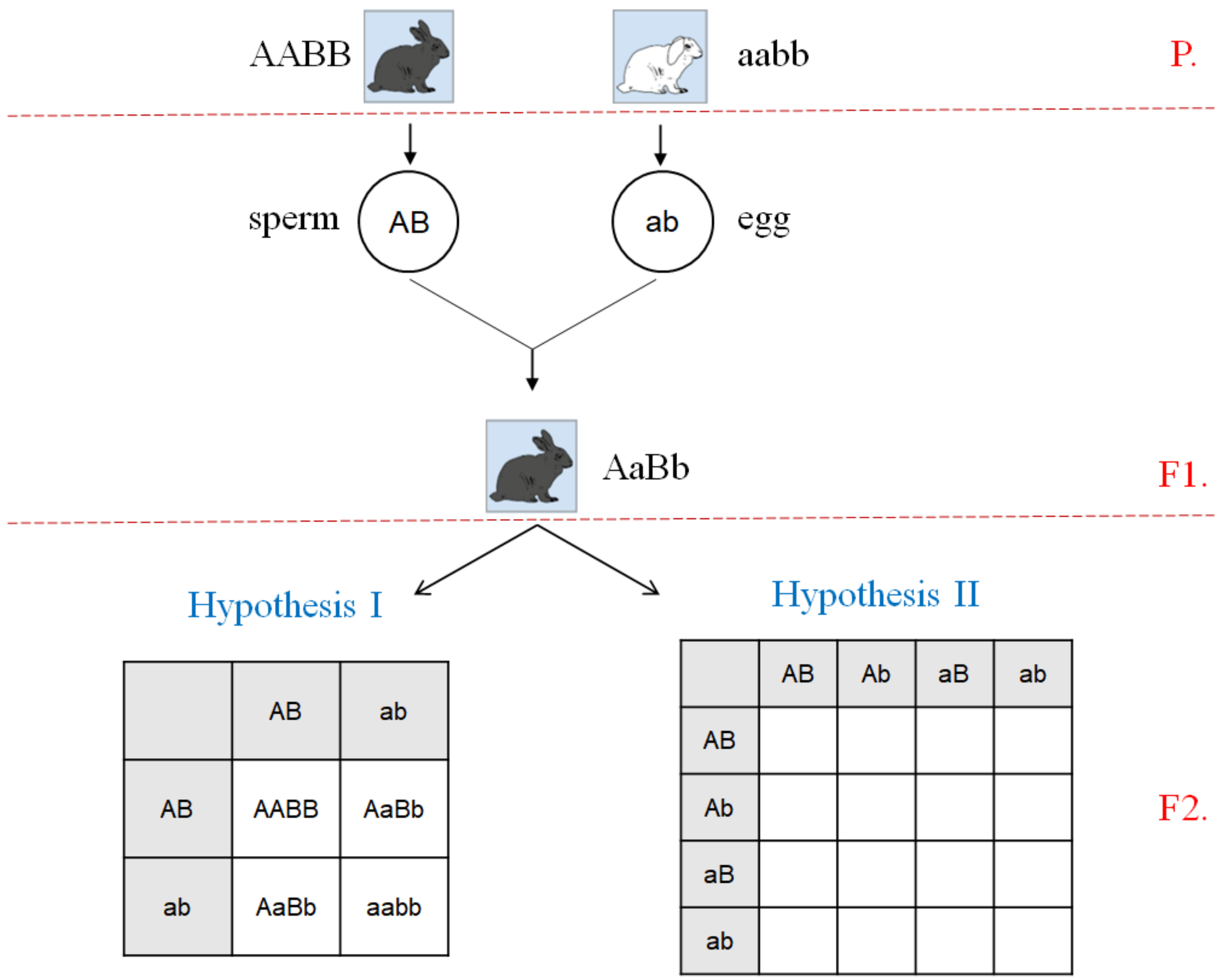

Figure 2

The two hypotheses of a dihybrid cross.

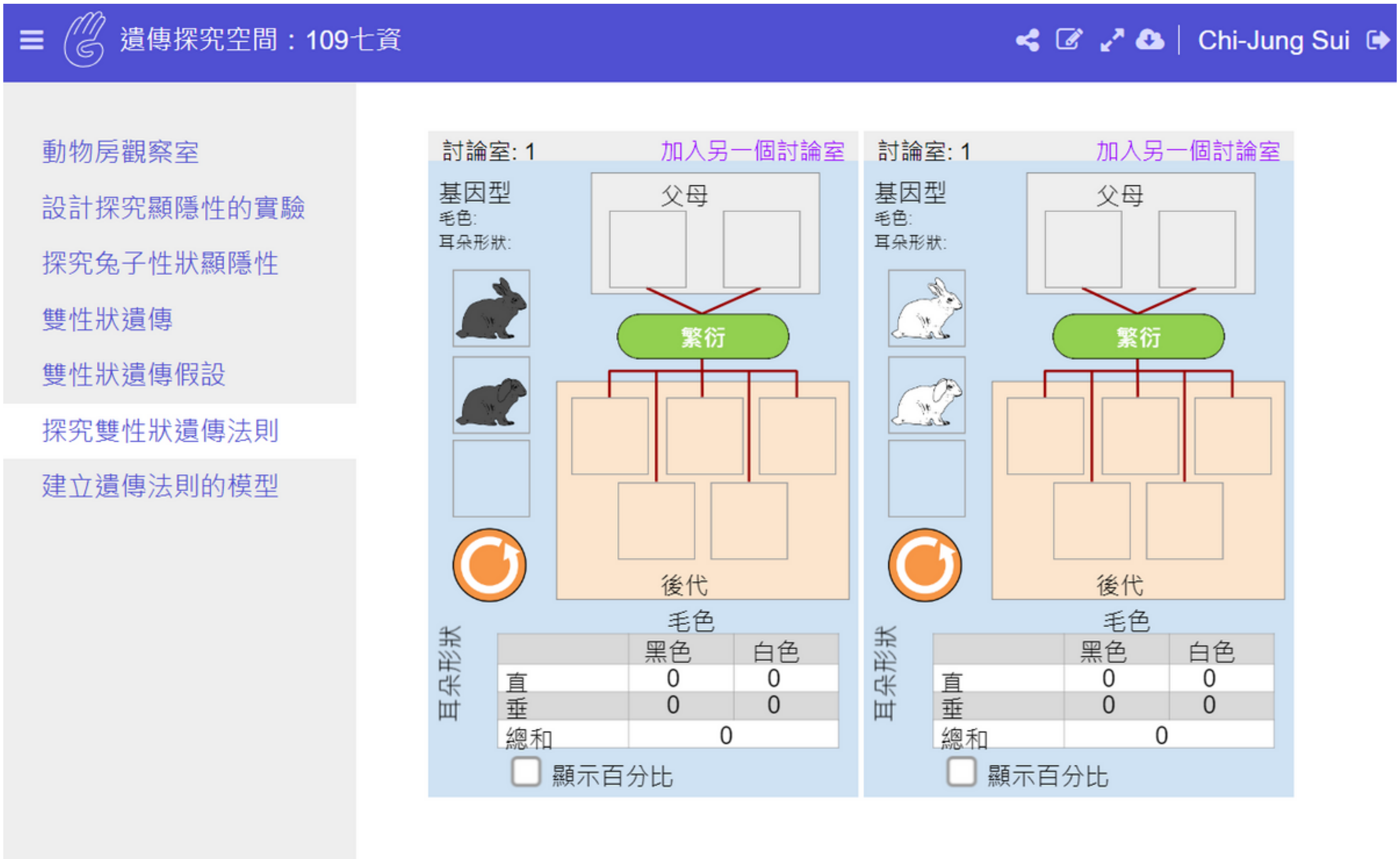

Figure 3

Screenshot of the ILS in the virtual lab.

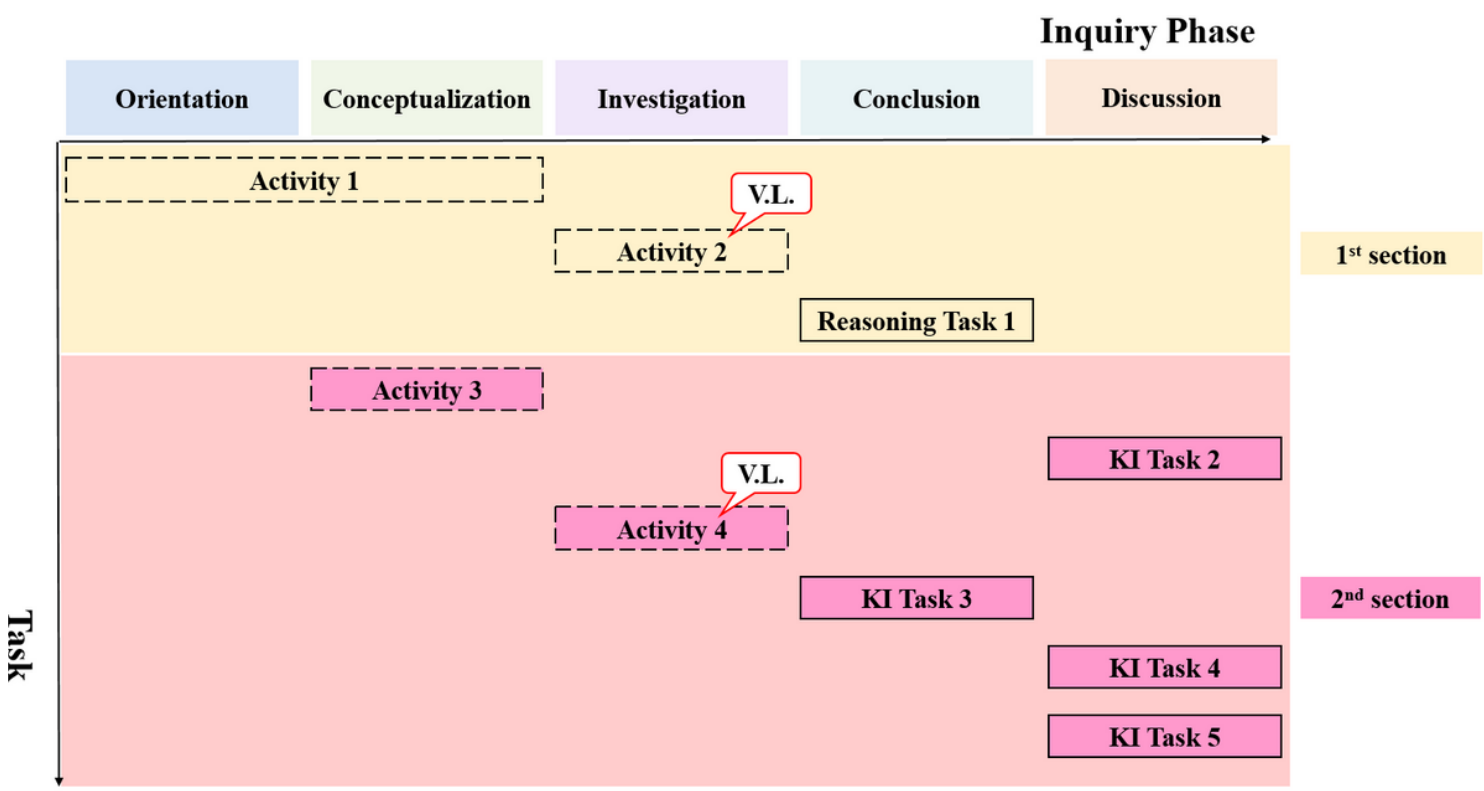

Figure 4

The learning tasks of the ILS. The red label “VL” referred to the virtual laboratory.

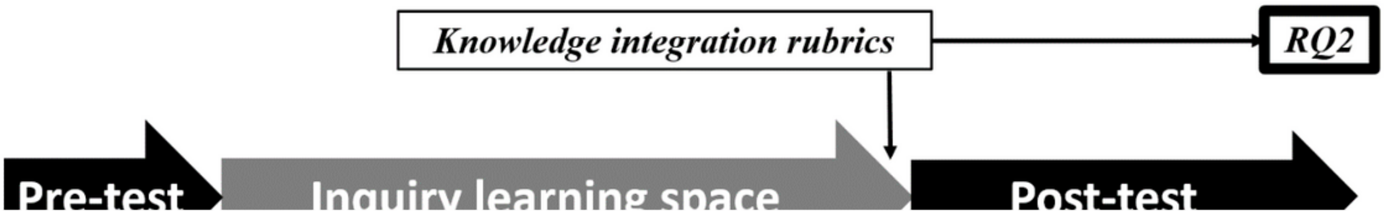

Figure 5

The procedure of this study.

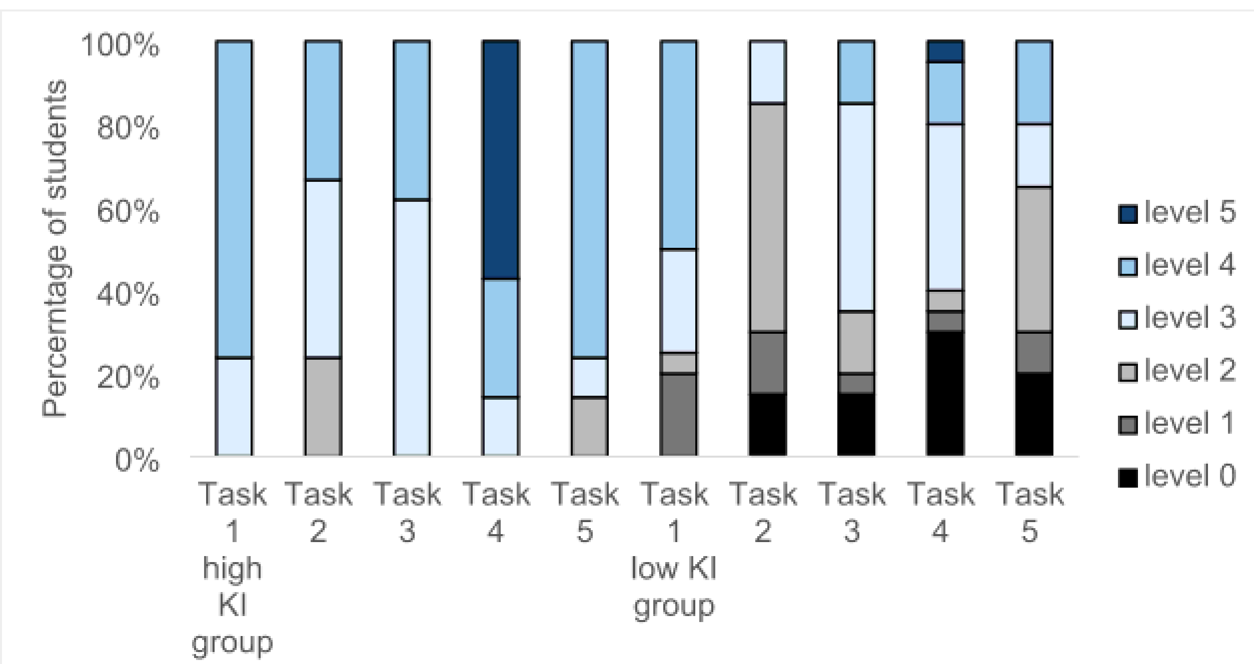

Figure 6

Percentage of students’ KI level according to each task.